

S Storm Lake Dam,
627.83 Anaconda, Montana,
U11sLd Deer Lodge County,
1981 MT 1357

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

STORM LAKE DAM
ANACONDA, MONTANA
DEER LODGE COUNTY

MT 1357

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prepared for:

HONORABLE TED SCHWINDEN
GOVERNOR, STATE OF MONTANA

ANACONDA COPPER MINING COMPANY
(OWNER / OPERATOR)

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prepared by:

HKM ASSOCIATES
BILLINGS, MONTANA

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Comments on Draft Report

Owner Comments on Draft Report

EXECUTIVE SUMMARY

Personnel of HKM Associates, under a contract with the Montana Department of Natural Resources and Conservation (DNRC), and with representation from the DNRC, and the Anaconda Copper Mining Company (project owner/operator), inspected Storm Lake Dam on September 30, 1980. The inspection and evaluation were performed under the authority of Public Law 92-367. Storm Lake is located 14.5 miles southwest of Anaconda, Deer Lodge County, Montana. The dam was constructed by the Anaconda Copper Mining Company. Available information indicates that the dam was completed in 1898.

FINDINGS AND EVALUATION

Storm Lake stores runoff from a drainage of 1.9 square miles. The primary purpose for stored water in Storm Lake is industrial water supply for the mining and smelting operation. Secondary benefits are provided for irrigation, municipal water supply, recreation, debris control, and flood control. Active storage capacity to the normal pool level is 1890 acre-feet (AF). Total storage capacity to first overtopping dam crest elevation is 2150 AF. Storm Lake Dam has a hydraulic height of 27 feet. On the basis of criteria in the U.S. Army Corps of Engineers' Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the dam is classified intermediate in size. Based on a visual reconnaissance and engineering judgment, at least three residences, as well as miscellaneous roads, bridges, utilities, and some agricultural land, will be affected by a sudden breach of the dam. The downstream hazard potential for the dam is, therefore, high (Category 1). No dam breach analysis or routing of a dam breach flood was made of the downstream area for the dam. The conclusions on probable damage are based on a brief field inspection and engineering judgment.

The guidelines recommend that the discharge and/or storage capacity of an intermediate-size, high downstream hazard potential dam be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Routing of the estimated PMF developed for the safety evaluation of Storm Lake showed that the project has the capacity for controlling a flood having hydrograph ordinates approximately equal to 33 percent of the PMF hydrograph ordinates.

Storm Lake Dam stability may conform to the Recommended Guidelines based on a visual observation. However, slope stability analyses are not available; the specific properties of the embankment and foundation materials are unknown; seepage

quantities are moderate; and the actual location of the phreatic surface through the embankment and in the foundation is unknown; therefore, embankment stability cannot be fully evaluated. Because the embankment and foundation material properties are unknown, potential for soil piping resulting from seepage cannot be evaluated. The riprap protection appears adequate up to the clayey sand layer which was placed in 1977. This layer is highly erodible and not adequately protected from erosion due to wave action.

The comparison of report findings with inspection guidelines shows the Storm Lake storage project to have insufficient storage and/or discharge capacity to safely handle the recommended spillway design flood (SDF), which is a full PMF. Because Storm Lake Dam cannot safely handle one-half the recommended SDF, it is considered unsafe-nonemergency until the recommended actions are complete.

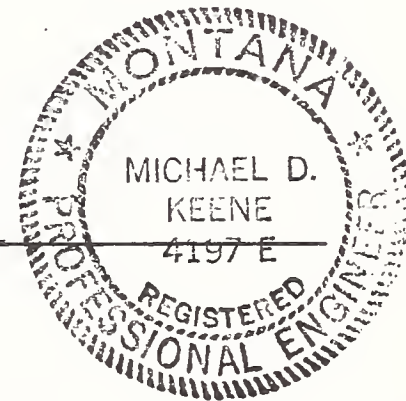
RECOMMENDATIONS

Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam distress. Coordinate the plan with emergency and operation plans for Silver Lake. Using suitable material, fill and properly compact all localized depressions along the dam crest. Place additional riprap along the upstream side of the dam crest to prevent wave erosion of the highly erodible layer on the crest. Perform the following repairs on the outlet works: perform a detailed evaluation of the condition of the outlet pipe and gatehouse and make the necessary repairs; repair the wooden flume and/or extend the metal pipe at the downstream end of the outlet works; provide the necessary means for energy dissipation if the outlet is modified; and consider adding an emergency closure valve at the upstream end of the pipe. Perform the following repairs on the spillway: repair the surface of the concrete sill in the spillway; remove the debris in the approach channel; and construct a log boom.

Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity and modify the project as studies indicate. Repair the erosion at the right abutment contact and on the dam crest. Monitor seepage flows periodically for evidence of boils, piping, and long-term changes in flow, and make changes if needed. Continue to monitor the riprap protection on the spillway approach channel sideslopes. Conduct an inspection with the presence of a qualified geotechnical engineer at least once every five years, and include an inspection of the total length of the outlet pipe in this program. Maintain an active maintenance program particularly with respect to the outlet works gates and debris removal in the spillway channel.

Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana DNRC, Dam Safety Section, to insure compliance with all pertinent laws and regulations.

Mike Keene
Michael D. Keene, P.E.



PERTINENT DATA SUMMARY

1. General

Federal ID Number	MT 1357
Location	Section 30, T4N, R13W, MPM; about 14.5 miles southwest of Anaconda, MT
County, State	Deer Lodge County, Montana
Owner and Operator	Anaconda Copper Mining Company
Purpose	Industrial water supply
Watershed	Storm Lake Creek
Drainage Area	1.9 square miles
Hazard Potential	Category 1 (High)
Size Classification	Intermediate

2. Reservoir

Surface Area at Normal Pool Level Elevation 8322.0 feet (see note page viii)	78 acres
Dead Storage Below Outlet Invert Elevation 8290 feet	Unknown
Active Storage to Normal Pool Level Elevation 8322.0 feet	1890 acre-feet
Flood Surcharge Storage to First Overtopping Dam Crest Elevation 8325.2 feet	260 acre-feet
Total Storage (not including dead storage) to First Overtopping Dam Crest Elevation 8325.2 feet	2150 acre-feet

PERTINENT DATA SUMMARY
(Continued)

Total Storage (not including dead storage) to Dam Crest Design Elevation 8327.0 feet	2300 acre-feet
Reservoir Water Surface Elevation on Day of the Inspection	8314.7 feet
3. <u>Outlet Works</u>	
Gate	Two 14-inch diameter valves located near downstream end of the system
Control	Manual operators
Pipe	About 400 feet of 14-inch diameter metal pipe in a masonry culvert with about 15 feet of wooden flume at the downstream end.
Capacity	
To Normal Pool Level Elevation 8322.0 feet	16 cubic feet per second
To First Overtopping Dam Crest Elevation 8325.2 feet	16 cubic feet per second
4. <u>Spillway</u>	
Type	Unregulated, trapezoidal rock spillway with concrete sill which acts as the crest.
Crest Elevation	8322.0 feet
Crest Width	31 feet
Side Slopes	Variable from 1V on 1.3H to 1V on 1.9H
Spillway Capacity to First Overtopping Dam Crest Elevation (8325.2 feet)	520 cubic feet per second

PERTINENT DATA SUMMARY
(Continued)

5. Dam

Type	Earth and rock fill
Structural Height	Approximately 29 feet
Hydraulic Height	27 feet
Design Crest Control Elevation	8327.0 feet
Existing First Overtopping Dam Crest Elevation	8325.2 feet
Crest Length	Aproximately 500 feet
Design Dam Crest Width	18 feet
Existing Dam Crest Width	Varies from 13 to 17 feet
Design Upstream Dam Slope	1V on 1.5H above elevation 8318 feet 1V on 3.5H below elevation 8318 feet
Existing Upstream Dam Slope	1V on 2H above elevation 8318 feet 1V on 3.8H below elevation 8318 feet
Design Downstream Dam Slope	1V on 1.5H
Existing Downstream Dam Slope	1V on 1.5H

Note: All project elevations are relative to local datum. The September 30, 1980 survey was based on the assumption that the average crest elevation of the concrete sill in the spillway corresponds with the normal water surface elevation 8322.0 feet shown on the project drawings.

CHAPTER 1 BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority

This report summarizes the Phase I inspection and evaluation of Storm Lake Dam. The project is owned and operated by the Anaconda Copper Mining Company.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive concensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

- (1) a limited investigation to assess the general safety condition of the dam
- (2) based upon an evaluation of the available data and a visual inspection
- (3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted
- (4) not intended to include extensive explorations, analysis, or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase

II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective action.

The responsibility for implementation of these Phase I recommendations rests with the State of Montana, Department of Natural Resources and Conservation and the owner. The owner is urged to contact the Montana DNRC prior to taking any action on report recommendations. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act, shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

The investigation process allows for report review by: the Montana DNRC, and the Anaconda Copper Mining Company (owner/operator). Review comments are considered before final publication of the Phase I Inspection Report. Their written comments are enclosed in Appendix E.

1.1.2 Purpose and Inspection

The findings and recommendations in this report were based on visual inspection of the project, minimal field survey measurements, and review of available design and operation data. The purpose of the inspection is to make a general assessment as to the structural integrity and operational adequacy of the dam embankment and its appurtenant structures. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

The visual inspection of Storm Lake Dam was made on September 30, 1980. HKM Associates personnel who attended the field inspection and contributed to this report were:

Dan Dyer, Geotechnical Engineer
Gary Elwell, Hydraulics/Hydrology
Mike Keene, Hydraulics/Hydrology, Team Leader

Other HKM personnel contributing to the report but not attending the field inspection were:

Dale R. Cunningham, Structural Engineer
Dan Nebel, Geology

Other personnel present during the September 30, 1980 inspection included:

Larry Tegg, Dam Safety Engineer, Montana DNRC,
Dam Safety Section
Ron Eccleston, Water Supply Foreman, Anaconda Copper
Mining Company
Charles Hill, Plant Coordinator, Anaconda Copper
Mining Company

1.2 DESCRIPTION

1.2.1 General

Storm Lake Dam is an earth and rock fill dam located in the NW 1/4 of Section 30, T4N, R13W, MPM, Deer Lodge County, Montana (Appendix A, Ref. 2, 3, 4, and Photos 1 and 2 of Appendix B).

The dam and reservoir form an industrial water supply facility within the Columbia River Basin by containing local runoff. Outlet releases provide water for Silver Lake located about 7 miles downstream of Storm Lake. The nearest downstream community is West Valley, Montana, which is located on Warm Springs Creek approximately 13 miles northeast of the dam (Appendix A and Ref. 3). There are several residences located in the flood plain of Storm Lake Creek and Warm Springs Creek. The location of Silver Lake is shown in Appendix A. A portion of a flood wave from a breach of Storm Lake Dam could be intercepted by the canal that supplies water from Twin Lakes to Silver Lake. It is assumed that the portion of the flood wave delivered to Silver Lake would be relatively small.

The Anaconda Copper Mining Company owns and operates the project.

Storm Lake Dam has a hydraulic height of 27 feet and impounds 2150 AF (excluding dead storage) at the first overtopping dam crest elevation (8325.2 feet, see note on page viii). Based on a visual reconnaissance and engineering judgment, at least three

residences, as well as roads, bridges, utilities and some agricultural land will be affected by a sudden breach of the dam. On the basis of this information and in accordance with the Recommended Guidelines (Ref. 1), the project is classified intermediate in size and the downstream hazard potential is high (Category 1).

Storm Lake Dam was constructed to provide storage and regulation in support of industrial operations. Incidental benefits are provided for floodwater detention, debris control, recreation, municipal water supply, and irrigation. Active storage to the normal pool level, or the spillway crest (elevation 8322.0 feet), is 1890 AF. An additional 260 AF is available for flood surcharge storage between the spillway crest and the first overtopping dam crest elevation.

A 14-inch diameter steel outlet pipe is located about 330 feet from the left (west) end of the dam. An unregulated trapezoidal spillway with a 31 foot wide bottom width is located on the left (west) end of the dam.

Storm Lake Dam has an upstream contributory drainage area of 1.9 square miles (Photo 3 of Appendix B). Storm Lake has an alpine watershed. Elevations in the basin range from 9990 feet NGVD to about 8180 feet NGVD at the reservoir (Ref. 6).^{1/}

1.2.2 Regional Geology

Storm Lake Dam is situated near the head of a glacial scoured gorge in the rugged Anaconda Range with numerous small cirques and tarn lakes in the immediate area. Precambrian and Paleozoic sedimentary rocks form the core of the range with Tertiary igneous rocks intruded throughout the area. The Tertiary igneous rocks form dikes, sills, stocks, and batholiths. Structurally, the area is highly complex with two major structural elements apparently exercising control over the local structural development. The first of these, which passes about 30 miles north of the dam, is the Montana Linament. The second is the Perry Line located far to the south. Both seem to be primarily fault structured and form a triangular block 125 to 150 miles wide at its western base within Montana and 150 to 200 miles long, pointing eastward. Structures within this block are generally the result of eastward directed compression. Locally,

^{1/} Basin elevations in feet National Geodetic Vertical Datum (NGVD) were obtained from the Storm Lake Quad map. All other elevations contained in this report are local datum.

thrust faulting is common and generally follows a north-south alignment, paralleling the major Phillipsburg thrust about 10 miles to the west (Ref. 5).

1.2.3 Seismicity

Storm Lake is in a moderately active to active seismic zone with the majority of the region's seismic events occurring in the Southwestern Montana-Yellowstone Park area. Since 1925, Montana has experienced five shocks that reached intensity VIII or greater (Modified Mercalli Scale). The closest epicenter occurred at Helena, Montana which is approximately 70 miles northeast of the damsite. Numerous other shocks of intensity IV or greater have been reported within a 100-mile radius of the site (as of January 1974). The site is located in Zone 3 of the Seismic Zone Map of Contiguous States, and it can be assumed that a major earthquake may occur within the life of the structure (Ref. 1, 6). Although the Zone Map is based on a known distribution of damaging earthquakes, it does not necessarily reflect accurate or adequate seismic design parameters for this site.

1.2.4 Local Geology

No reconnaissance geologic reports or subsurface information for the dam are available. This section is based on geological and topographic map interpretation.

The Storm Lake drainage was occupied by one of several large glaciers headed on the north flank of the Anaconda Range. These glaciers joined two or three that headed on the Flint Creek Range and coalesced to form a trunk glacier extending down Warm Springs Creek. It appears that Storm Lake Dam raised an existing cirque lake formed behind a recessional moraine. The recessional moraine was bisected by Storm Lake Creek with spurs now extending from the valley walls across all but a small portion of the floor. Storm Lake Dam spans the bisected portion of the moraine. Storm Lake Dam appears to be resting on glacial deposits which extend to an undetermined depth. The glacial deposits consist of a heterogeneous mixture ranging in size from clay sized materials to boulders. Pervious layers of fluvial (outwash) gravel are common and provide a course for seepage.

1.2.5 Design and Construction History

Storm Lake Dam was designed and constructed by Anaconda Copper Mining Company. Some background information identifies WASHO Copper Company as the engineer and construction group. As explained by the plant coordinator and water supply foreman, WASHO Copper Company was a part of the Anaconda Company.

Available information indicates that Storm Lake Dam was completed in 1898. Only three drawings of the project were provided for review, and none of the drawings were dated or marked "as built". The drawings are entitled: Storm Lake, Dam at Storm Lake, and Map of Storm Lake Reservoir. No other information was available for review.

Modifications to the project since original construction include raising the dam embankment and rehabilitating the outlet works gatehouse. A slight overtopping of the dam embankment by waves occurred about 3 years ago due to debris clogging the spillway. Approximately 2 feet of fill material was placed on the dam embankment as repair and to provide a small amount of additional embankment height. The fill material is described as being highly erodible clayey sand.

A new roof was placed on the outlet works gatehouse about five years ago. Additional work included placing timber cribbing on the interior of the valve pit. The cribbing was required to improve the deteriorating structural integrity. Operation of the operating gate (the furthestmost downstream valve in the pit) has been made more convenient by fabricating an extension on the operating key and providing a small hole in the gatehouse roof. This improvement permits valve operation (downstream valve only) from the gatehouse roof as opposed to inside the small valve pit.

Repair and maintenance records are not available, evidently because there have been so few major problems requiring documentation.

CHAPTER 2 INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

The hydraulics and structures evaluation included a review of project data and a field inspection. The field inspection included photo documentation, field measurement, and a field survey of required elevations. Inspection photos are located in Appendix B, a few construction drawings are provided in Exhibit C1 of Appendix C, the crest profile is shown in Exhibit C2, and the spillway plan and profile are included in Exhibit C4.

2.1.1 Spillway

The spillway for Storm Lake Dam is located on the left (west) end of the dam (Photo 1 of Appendix B). The spillway is composed of an entrance, an approach section, a control section, and a return channel.

The spillway entrance makes a gradual transition from the reservoir pool to the spillway approach channel. The spillway entrance has a base width of 25 feet, a top width of 40 feet and bank heights of about 6 feet.

The spillway approach section is straight, uniform, and is trapezoidal in shape. The base width is 25 feet and bank height varies from 6 to 10 feet. The approach has a length of about 160 feet from the entrance to a concrete sill which acts as the control for most flows. The approach channel is lined with hand-placed riprap (Photo 4 of Appendix B).

A concrete sill, which acts as the control for all but the highest flows, is located at the downstream end of the control section. The concrete sill has an average crest elevation of 8322 feet (see note on page viii) which is approximately 1 foot above the channel bottom. The concrete sill is approximately 30 feet wide and 24 inches thick with a slightly rounded top. The channel banks at the sill are about 6 feet high and have side slopes of 1V on 1.7H (Photo 5 of Appendix B).

There is a break in slope about 55 feet downstream of the concrete sill. The base width at this point is 23 feet and the banks are not very well defined. At high flows, when the concrete sill is submerged, control is located at this section (Photo 5 of Appendix B).

Water flows over the natural terrain downstream of the break in slope. There is no particular energy dissipation facility where

spillway flows return to Storm Lake Creek. Energy is dissipated by cascading water and the spreading out of the water due to an increased flow area. The valley downstream of the return point is about 200 feet wide (Photo 5 of Appendix B).

The spillway entrance and approach are in good condition. Minor riprap sloughing has occurred in the approach section. The approach section also contained a significant amount of debris. This debris consists primarily of timber carried down the steep basin slopes by snow avalanches each year. This timber debris is generally burned yearly, but was not burnt this year due to lack of personnel as the result of strikes. There is no log boom.

The concrete sill is in very poor condition. The concrete is experiencing cracking and spalling. At the time of the investigation, a large amount of timber debris was collected against the upstream side of the sill. As stated above, this material is generally burned yearly.

The channel between the concrete sill and the break in slope is in satisfactory condition.

The upstream end of the return channel has experienced erosion and the banks are vertical in places. Further downstream there are few signs of aggradation/degradation. The lower end of the return channel has many spruce trees and a large amount of brush cover.

The water supply foreman indicated the spillway generally flows every year with a maximum depth of 12 inches in most years. The amount of debris collected by the spillway can significantly reduce the maximum discharge capacity of the dam. The trees and brush at the bottom of the return channel do not significantly affect the spillway capacity. Dam personnel stated the dam was slightly overtopped by waves approximately 3 years ago as the result of a clogged spillway.^{1/} It appears approximately 50 feet of earthen material would have to be eroded away before damage would occur to the dam embankment. Therefore, the spillway appears to be located a safe distance from the dam embankment.

Spillway hydraulic rating information is not available. Therefore, new rating information was developed using the U.S. Army Corps of Engineers' computer program HEC-2 (Ref. 7). Calculations were performed assuming a Manning's "n" of 0.03 and that spillway flows pass through critical depth at the break in

^{1/} Routing results indicate the flood handling capability for large floods is not very sensitive to spillway capacity (see Section 2.2.3).

slope. The slope of the return channel is assumed to be steep enough to prevent backwater effects. HEC-2 results indicate spillway control occurs at the concrete sill up through 100 cfs. Between 100 and 300 cfs control shifts downstream to the break in slope as a result of the concrete sill being totally submerged.

Spillway capacity to the first overtopping dam crest elevation 8325.2 feet is 520 cfs. Final spillway rating data is presented in Exhibits D2 and D3 of Appendix D.

2.1.2 Outlet Works

The outlet works for Storm Lake Dam is located about 330 feet from the left (west) dam abutment contact and aligned approximately perpendicular to the dam crest. The outlet works consists of an inlet structure, a 14-inch diameter metal pipe, a gatehouse, and an outlet structure.

Specific information relating to the inlet structure and the pipe through the embankment is extremely limited. A project drawing (Exhibit C1 of Appendix C) indicates the inlet invert elevation is 8290 feet (see note on page viii) and the metal pipe is in a masonry culvert. It is not known whether the metal conduit is grouted or free within the masonry culvert. The drawing indicates the pipe has a length of 400 feet from inlet to outlet.

The gatehouse is located about 30 feet beyond the downstream toe of the dam. The exterior of the gatehouse is constructed with concrete, mortar and rock. Timber cribbing is located on the inside of the structure. A new roof, installed 5 years ago, covers the gatehouse. A hatch in the roof allows access to the gatehouse. There are two gate valves located in the gatehouse. The upstream gate functions as an emergency valve and the downstream valve is used for operational purposes. A small opening in the roof of the gatehouse allows operation of the downstream gate from outside of the gatehouse (Photo 6 of Appendix B). Since the valves are located beyond the downstream toe of the dam, the conduit through the embankment is subject to the full head of the reservoir when either valve is closed. A leak in this pressurized conduit could lead to dam failure. This is especially significant because this is an old dam and the condition of the metal conduit is unknown. However, if there is an air space between the metal conduit and the masonry culvert, a pressure build-up adjacent to the embankment material would be less likely.

A wooden flume is located at the pipe outlet. The flume is buried for about 15 feet before daylighting. The end of the flume is about 100 feet downstream of the embankment toe. Energy

dissipation is provided by pool water and large rock immediately downstream of the flume where water returns to Storm Lake Creek. Water continues downstream along a relatively steep gradient (Photo 7 of Appendix B).

The inlet structure and the interior of the outlet pipe could not be inspected due to the high pool level at the time of the survey and the small diameter of the pipe.

The exterior of the gatehouse has deteriorated significantly. Cracking, chipping and spalling is present in the concrete. Cracking of the mortar is evident throughout the rock (Photo 6 of Appendix B). The mastic or asphaltic material has separated from the joint between the wood roof and the masonry. Some of the wood material in the hatch cover has been eaten away by wood chucks. The interior of the masonry walls is also badly deteriorated. However, the gatehouse is in stable condition because of the large timber cribbing.

Both valves in the gatehouse were under water. The water supply foreman indicated they have been submerged for years, but he felt it has had no adverse effects on the valves. There was no evidence of damage. To the best of his knowledge, both valves are fully operational. At the time of the inspection, the downstream valve was fully closed to test its operation capability. It could not be determined if a complete seat was obtained due to the standing water and seepage flows at the outlet of the wooden flume. It is assumed a good seat was obtained, since there was no sound indicating seepage around the valve. When the valve was near full closure, leakage was present around the valve stem. This leakage disappeared with full closure of the valve. The upstream or emergency valve was not operated during the inspection. The water supply foreman indicated the emergency valve is seldom operated, except for breaking the seat occasionally to prevent the valve from mechanically "freezing" in place. He believed the valve is fully operational and could not recall any maintenance requirements on either of the valves.

The wooden flume, located at the downstream end of the pipe, is in very poor condition. Between 30 and 50 feet of the original wood flume is missing according to the water supply foreman. It is not possible to see the steel pipe when it enters the wooden flume because it is buried. Erosion is present along the channel banks downstream of the flume. The banks are vertical in some places and soil sloughing has occurred. A small amount of backcutting has occurred at the outlet along with local erosion on both sides of the outlet caused by seepage from the dam.

The outlet is about 100 feet downstream of the embankment toe and, therefore, should not endanger the dam embankment during high discharges. The only thing that could reduce the maximum discharge capability would be the deterioration of the remainder of the wooden flume at the downstream end of the metal pipe. The hatch cover on the gatehouse roof is ordinarily locked, but due to animal damage the hatch cover can no longer be locked. A small opening is provided in the roof to allow operating the downstream gate from outside of the gatehouse, but operation from outside requires a special tool available only to dam personnel. The upstream gate must be operated from inside the gatehouse. Access to the gatehouse during a flood event could be extremely difficult as the access road crosses Storm Lake Creek a few times downstream of the dam.

Outlet works releases are generally made in August and September to provide water to Silver Lake.

Hydraulic rating information is not available. Therefore, the rating information was developed using the energy equation. Calculations were performed assuming a Manning's "n" of 0.013 and pressure pipe flow throughout the pipe. Discharge capability is 16 cfs to the spillway crest elevation 8322.0 feet (see note on page viii) and 16 cfs to the first overtopping dam crest elevation 8325.2 feet. Complete outlet works rating information is provided in Exhibits D2 and D3 of Appendix D.

2.1.3 Freeboard

Flood routing (Section 2.2.3) indicates the dam overtops during the guidelines' (Ref. 1) recommended spillway design flood (which is the full PMF), and therefore, no freeboard exists for such conditions. The vertical distance from the spillway crest (elevation 8322.0 feet, see note on page viii) to the first overtopping dam crest elevation (8325.2 feet) is 3.2 feet. The water supply foreman indicated that a probable historic highwater elevation for Storm Lake Dam is about 8323.0 feet, or a vertical distance of approximately 2.2 feet below the September 1980 first overtopping elevation. The vertical distance between the reservoir pool and the first overtopping elevation at the time of the September 1980 field inspection was 10.5 feet.

Storm Lake is basically oriented in a north-south direction, with the dam on the north side. The prevailing wind for this region is generally identified as being westerly (Ref. 8, 9). The reservoir location and orientation can be observed in Appendix A. Based on an effective fetch length of less than 1 mile, the minimum freeboard allowance should be about 3 feet (Ref. 10). The vertical distance between normal pool level and first overtopping dam crest elevation is sufficient to prevent overtopping by wind-generated waves.

2.2 HYDROLOGY

2.2.1 Physiography and Climatology

Storm Lake has a 1.9-square mile catchment area, which is approximately square in shape. The average width and length is just under 1.5 miles (Appendix A). The topography is comprised of alpine terrain. The catchment area is a quick response watershed.

Soils in the Storm Lake drainage area are classified as Alpine-Rockland. "These are areas dominated by shallow and very shallow soils and rockland on very steep high mountain peaks" (Ref. 11).

The climate of the region may be classified as modified continental, occasionally reflecting tendencies to be similar to higher elevation Pacific slope climates. This area exhibits marked seasonal variations in climate, with differences in distribution of monthly average precipitation between mountain and valley areas. Specific to the moisture-runoff characteristics of the Storm Lake basin, runoff is derived chiefly from melting snow. In general, the valleys are relatively dry during the colder months and wet during the late spring and early summer. The wettest part of the year in the mountains is generally from midwinter to early spring. The average annual precipitation for the climatological station at Silver Lake, located about 6.5 miles north of Storm Lake, is 18.8 inches. The mean annual precipitation on the Storm Lake drainage basin may be near 40 inches.

Average annual temperature for East Anaconda, about 16 miles east of Storm Lake, is 42 degrees F. Winters are typically cold, with January being the coldest month. The monthly average temperature for January in East Anaconda is 22 degrees F. Summers, although fairly warm, seldom produce oppressive heat. Even the warmest summer days are followed by pleasantly cool nights. July is commonly the warmest month of the year for this region, with an average monthly temperature of 66 degrees F. at East Anaconda. The average number of days between the last recording of 32 degrees F. in the spring and the first in the fall is about 110 at East Anaconda (Ref. 8 and 9).

No natural streamflow measurements are available in the area.

2.2.2 Estimated Probable Maximum Flood (PMF)

The probable maximum precipitation (PMP) and the estimated probable maximum flood were developed for the Storm Lake drainage basin. The ratio of the reservoir area to the non-reservoir area

is greater than 1 percent, therefore the two areas are separated for the purpose of this analysis. The PMF is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the study region.

Storm Lake is located west of the Continental Divide, and hence, general storm and thunderstorm PMP values were calculated using procedures contained in the National Weather Service's Hydrometeorological Report No. 43 as updated by the 1967 memo (Ref. 12). Snowmelt was estimated based on techniques in HMR 43 and "Runoff from Snowmelt" by the U.S. Army Corps of Engineers (Ref. 13) for use with the general storm. The thunderstorm PMP was assumed to be a critical event for this small basin because Storm Lake has a relatively low surcharge storage and outflow capacity and, therefore, is more sensitive to runoff peak than runoff volume. Thunderstorm PMP values for durations up to 6 hours were estimated using HMR 43. The 1967 memo allows for some reduction of the PMP that was not originally contained in HMR 43. The 1/2 hour, 1-hour, 3-hour, and 6-hour precipitations are 5.3, 7.2, 8.6, and 8.8 inches, respectively. It was found that the highest thunderstorm PMP value occurs during the month of August. Subdivision of the calculated rainfall increments was required to provide compatibility with the duration of the unit hydrograph. A 2-minute unit hydrograph was selected for Storm Lake using criteria presented in the SCS Hydrology Handbook (Ref. 14). The August PMP storm was plotted in the form of a depth-duration curve for convenience in selecting incremental rainfall values. The 2-minute August PMP values were ordered according to the reverse pattern of the unit hydrograph ordinates.

It is assumed that a saturated soil condition could exist prior to the PMP storm. However, there is still potential for minimum retention losses to the soil. Therefore, a loss rate of 0.02 inches/hour, based on minimum loss rates for soils such as those found in the basin, was used in the computations.

The runoff condition, or PMF, resulting from an August PMP thunderstorm was estimated using the PMP values and the unit hydrograph approach. A 2-minute unit hydrograph was developed for the Storm Lake basin using the SCS method (Ref. 14) and the U.S. Army Corps of Engineers' computer program HEC-1 (Ref. 15). The resultant August PMF has a total runoff volume of 880 AF.

2.2.3 Flood Routing

The PMF was routed through Storm Lake using the computer program HEC-1 (Ref. 15). Runoff from an antecedent storm was not specifically considered; however, it appears reasonable to assume the initial reservoir level prior to routing the PMF is at the

spillway crest (elevation 8322.0 feet, see note on page viii). The support rationale for this assumption is that the water users would prefer to store as much water as possible in preparation for irrigation, municipal, and industrial uses. Drawdown of the reservoir pool can be accomplished with the 14-inch diameter outlet pipe. However, it is not likely that the project would be operated in this manner unless it was an emergency measure. The "sense of emergency" is not likely to be realized by the project operators to the extent storage water would be sacrificed in anticipation of the PMF event.

Reservoir area-capacity-elevation data and hydraulic rating data was not available. Area-capacity-elevation information was obtained by planimetering a contour map from the project file (Ref. 4). Sediment is not a significant factor at Storm Lake, and it is assumed that the storage capacity has not changed substantially due to sediment accumulation. New hydraulic rating information was developed. For routing purposes it was assumed that the amount of flow through the outlet works would be insignificant relative to the total flood runoff.

For the purposes of flood routing and according to Phase I investigation criteria, the minimum dam crest elevation is the elevation at which overtopping of the dam will occur. This criteria assumes overtopping and failure of embankment-type dams to be coincidental. Based upon the dam crest profile surveyed on September 30, 1980 (Exhibit C2 of Appendix C), first overtopping will occur at an elevation of 8325.2 feet.

Flood routing showed that the dam would first overtop during the PMF when approximately 32 percent of the total PMF volume enters the reservoir. Routings were made of lesser hypothetical floods than the PMF to determine the magnitude of floods the dam can contain. The hypothetical hydrographs are obtained by applying percentages to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to 33 percent PMF ordinates is just controlled by the project. Larger floods would overtop the dam.

Flood routing was also performed using 50 percent of maximum spillway capacity to simulate the effect of a clogged spillway. Results indicate a 50 percent reduction in spillway capacity causes an increase in maximum reservoir pool level of only 0.1 foot during the PMF. The effect of a clogged spillway may be more significant during a smaller flood.

2.3 GEOTECHNICAL EVALUATION

The geotechnical evaluation of Storm Lake Dam included a field investigation and a search and review of project data. The field

inspection consisted of photo documentation, a dam crest profile survey, slope stability observations of the dam embankment, seepage observations, and measurements of the slope angles. Inspection photos are included in Appendix B, a few construction drawings are included in Exhibit C1 of Appendix C, and the crest profile survey is shown in Exhibit C2. Results of the slope angle measurements are provided in Exhibit C3.

2.3.1 Dam Embankment

Storm Lake Dam is an earth and rock fill structure which was completed in 1898. The dam has an estimated structural height above the deepest point on the foundation surface of 29 feet, a hydraulic height of 27 feet and a crest length of 500 feet. There is an open channel spillway on the left (west) end of the dam. The drawings (Sheet 2 of Exhibit C1 of Appendix C) indicate the dam crest width was designed to be 18 feet (Photo 8 of Appendix B). Field measurements indicate the crest varies in width from 13 to 17 feet which is 1 to 5 feet less than shown on the construction plans. There is a layer of highly erodible clayey sand about 2 feet thick across the dam crest (Photo 8 of Appendix B). An employee of the Anaconda Copper Mining Company indicated during the field inspection that this layer was placed in 1977 to create a uniform and constant crest elevation and to repair damage done near the left abutment during overtopping by high wave action. The narrower crest width appears to be the result of erosion of the outside edges of the sand layer and dimension irregularities during construction of this layer.

One of the available drawings (Sheet 2 of Exhibit C1) indicates the upstream face of the main dam embankment has a slope of 1V on 1.5H down to elevation 8318 feet (see note on page viii), then flattens to 1V on 3.5H. The drawings indicate there is a 7.5 foot wide bench located at elevation 8320 feet. The drawing also indicates that wave protection is provided by paving which appears to refer to loose rock riprap (Photo 9 of Appendix B). A slope of 27 degrees (1V on 2H) was measured on the existing slope above elevation 8318 feet and slope measurements below varied from 14 to 15 degrees (1V on 3.8H), which is also slightly flatter than shown on the plans. There was some scattered debris evident on the upstream slope (Photos 9 and 10 of Appendix B).

The drawing indicates the downstream face of the dam was designed with a slope of 1V on 1.5H (Sheet 2 of Exhibit C1). Field measurements averaging about 33 degrees verify this slope. The surface of the downstream slope was loose rock (Photo 11 of Appendix B). This slope was relatively uniform.

Drawing details provided on Sheet 2, Exhibit C1 indicate the embankment cross section consists of four zones - a clay zone, a

dry slope wall, a rock fill, and riprap paving. Each zone includes a triangular shaped key located at the base of the embankment. A detailed description of the embankment materials was not available. As-built plans were not available for review. There is no evidence that there is a clay zone in the embankment.

There is an area of fill material downstream of the embankment (Exhibit C3 of Appendix C). Based on field observations, this material appears to be waste from the original construction. These materials do not create a safety hazard. In fact, the position of this fill adds stability to the embankment.

Construction specifications were not available for review and there was no record of construction quality control.

The drawings (Sheets 2 and 3 of Exhibit C1 of Appendix C) indicate that the dam crest control was established at elevation 8327 feet. An embankment profile was surveyed during the field investigation (Exhibit C2 of Appendix C). The survey shows that the maximum differential elevation along the main embankment crest is about 1.5 feet with a low point at elevation 8325.2 feet. Information provided by an employee of Anaconda Copper Mining Company indicates that the clayey sand layer along the crest (Photos 8 and 9 of Appendix B) was placed in 1977 because of damage to the crest, therefore, settlements cannot be evaluated based on this survey.

2.3.2 Foundation Conditions and Seepage Control

No records of test holes were available for review. Apparently no soil tests were performed during the design of the embankment.

The foundation conditions are unknown. Based on geologic features and visual inspection of the topography at the embankment locations, it is likely that the dam is resting on shallow alluvial deposits of clay, sand, and gravel. There is no evidence that there are any soft or weak zones in the embankment foundation.

Seepage

According to the drawings by the Anaconda Copper Mining Company (Sheet 1-3 of Exhibit C1 of Appendix C) there is no cutoff trench or seepage control drain system under the dam. At the time of the September 1980 field investigation, Storm Lake was at elevation 8314.7 feet, which is approximately 10 feet below the low point on the dam crest. Moderate seepage was observed (Exhibit C3 of Appendix C). Water was apparently seeping through

and/or under Storm Lake Dam saturating the downstream valley floor area. The downstream rockfill section of the embankment is a free draining material thus preventing seepage from exiting on the downstream embankment face (Photo 12 of Appendix B). Seepage water had ponded at one location at the downstream toe of the embankment (Photo 13 of Appendix B). Many springs were evident throughout the downstream area (Photo 14 of Appendix B). All springs and seepage water were flowing clear at the time of this investigation. Surface flow from the accumulated seepage was estimated during the field investigation to be about 50 gallons per minute. It is likely that seepage increases in this area when the pool elevation rises. The drawing (Sheet 2 of Exhibit C1) suggests there is a zone of material between the upstream clay and downstream rock zones. This zone may be a filter material, however, there is no other evidence that it is a filter.

In conclusion, there was a moderate quantity of seepage from the dam. The seepage creates saturated foundation soils conditions, however, the rockfill portion of the embankment is controlling seepage from exiting on the downstream face. The phreatic surface through the embankment is unknown. Apparently there is no seepage control system in the foundation and the natural foundation and embankment soils are relatively pervious.

2.3.3 Stability

The slope angles measured during the field investigation are shown in Exhibit C3 of Appendix C. These angles were measured with an Abney Level and should be considered approximate.

There was no stability analysis data available to evaluate the slope design for the dam. Apparently no soil strength tests were performed and stability calculations were not made. The specific properties of the embankment and foundation materials are unknown. The location of the phreatic surface through the embankment and foundation is also unknown.

No sand boils or piping soils were observed. The potential for piping is unknown because the properties of the embankment and foundation materials are unknown. The liquefaction potential is unknown.

Large snow slides and minor land slides have occurred along the reservoir shoreline (Photo 15 of Appendix B). The snow slides are potentially dangerous as one could create a large wave which may overtop the embankment. The shoreline was occasionally vertical, or near vertical, to heights of about 10 feet and localized sloughing occurs due to wave action and saturated conditions.

There were no outward signs of instability. Moderate seepage quantities were observed through and/or under the dam. The downstream slope was steep, 1V on 1.5H, however, the material appears to be high strength, free draining rockfill (quartz and monzonite). The embankment slopes are relatively uniform. Because the embankment is very old (constructed in 1898) and the downstream portion is a rockfill, and because the embankment does not appear to have experienced any significant deformation, in our judgment, the embankment stability may conform to the Recommended Guidelines.

The side slopes of the open channel spillway are in good condition. Some minor sloughing of the rock riprap lining of the channel has occurred but this sloughing does not create a safety hazard.

Erosion

There are several locations along the crest where water has ponded in depressions caused by vehicular traffic. At locations where water has spilled from these ponds down the slope, small erosion gullies have formed (Photo 16 of Appendix B). These gullies do not create a safety hazard.

At the right abutment contact near the downstream toe, there was some erosion evident. This erosion was the result of vehicular traffic ruts traveling parallel to the direction of runoff flows. This erosion does not create a safety hazard.

2.3.4 Rock Riprap

There was a loose rock riprap protection blanket on the upstream face of the embankment. The drawing (Sheet 2 of Exhibit C1 of Appendix C) indicates this blanket was to have been 24 inches thick. The rock was well indurated quartz and quartz monzonite. This riprap was in excellent condition, however, it did not extend high enough to protect the recently placed, highly erodible material on the crest from erosion due to wave runup.

There was a small amount of riprap at the downstream end of the outlet works, however, the natural rock in the channel in combination with the riprap provides adequate erosion protection for the conduit flow.

The riprap in the spillway has slid down the slope in some places but this movement did not expose erodible soils. Riprap sloughing in the spillway may be a problem in the future. Preventive maintenance may be needed in the near future.

In conclusion, the riprap protection at Storm Lake Dam appeared adequate, except for the upstream side of the crest.

2.4 PROJECT OPERATIONS AND MAINTENANCE

Storm Lake is owned and operated by Anaconda Copper Mining Company. The primary purpose for stored water in Storm Lake is industrial water supply for the mining and smelting operation. Incidental benefits are provided for municipal water supply, irrigation, recreation, flood control, and debris control.

The project has a general operation plan which is dictated by seasonal runoff/storage, and downstream water requirements. Storm Lake is filled primarily by snowmelt and/or snowmelt combined with rainfall runoff in the spring and early summer months. Typically, Storm Lake is filled by late June or early July. Related to reservoir filling is spillway operation, which is generally described as operating every year. However, it is generally not possible to observe and monitor spillway operation because of site inaccessibility at that time of year. Occasionally, the site is visited early in the runoff season using snowmobiles. Storm Lake spillway flows are diverted to Silver Lake for reregulation purposes.

Controlled releases from Storm Lake are made in August and September. On an annual basis, the reservoir is generally lowered about 25 feet below the normal water surface to provide reregulation storage water to Silver Lake and to vacate the pool for next year's runoff. Occasionally the controlled release routine extends into the fall months to achieve the desired drawdown. The outlet works gate is left slightly open year around to pass the natural base flow of the basin and to combat freeze problems.

One significant operational constraint for Storm Lake is its remoteness. The storage project is located almost eight miles off a main highway, three miles of which is classified a jeep trail. The site is accessible by a four-wheel drive vehicle only a few months out of the year.

There are no gages or formal plan for measuring flows on Storm Lake Creek or storage at Storm Lake. Flows diverted from Storm Lake Creek to Silver Lake are measured by the water supply foreman on a daily basis during the diversion period. An occasional approximate Storm Lake pool level is obtained using a hand level and measuring rod.

General inspections of the storage project are made at least twice, and sometimes as much as six times a year by the water supply foreman and plant coordinator.

There was no formal maintenance plan for Storm Lake. As described by the plant coordinator and water supply foreman,

major maintenance or repair on the dam or appurtenances is performed as needed by Anaconda Copper Mining Company personnel and equipment. However, the project is described as being generally free of maintenance requirements. Two modifications which have relative importance are the repair and raising of the dam embankment following a slight overtopping in 1977, and the rehabilitation of the outlet works gatehouse (see Section 1.2.5 for details). The gate valves in the gatehouse have not required much maintenance. The operating gate (furthestmost downstream valve) is operated on a regular basis throughout its total range of travel, whereas the emergency gate (upstream valve in the gatehouse) is operated only occasionally to verify operational capabilities. The gatehouse is designed with a security provision to discourage unauthorized operation of the gates. However, the lock on the hatch cover is not functional at this time. A regular maintenance activity includes burning the debris, primarily drift wood, which accumulates in the spillway channel.

There was no formal warning plan of action in the event of dam distress. Though not part of a formal plan, a distress condition would be communicated by phone, radios, and door-to-door contact.

CHAPTER 3 FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in accordance with the guidelines (Ref. 1) and the contract performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification and Safety Evaluation

In accordance with the inspection guidelines (Ref. 1), Storm Lake Dam is classified intermediate in size and, based on our visual inspection and engineering judgment, it has a high downstream hazard potential. Therefore, the guidelines' recommended spillway design flood (SDF) for this project is 100 percent of the PMF. Based on reconnaissance level investigations, the project is incapable of handling a flood having one-half the PMF ordinates without overtopping and causing the dam to fail which, in our judgment, could seriously jeopardize life and property downstream. Under inspection guideline criteria, Storm Lake Dam is considered unsafe-nonemergency until the recommended actions are complete.

3.1.2 Dam

The Storm Lake Dam embankment is very old, yet the slopes are relatively uniform. Because the downstream portion of the embankment is rockfill and because the embankment does not appear to have experienced significant deformation, in our judgment, Storm Lake Dam stability may conform to the Recommended Guidelines. However, slope stability analyses are not available; the properties of the embankment and foundation materials are unknown; seepage quantities are moderate; and the actual location of the phreatic surface through and under the embankment is unknown; therefore, embankment stability cannot be fully evaluated. It is unknown whether there is a filter coarse between the clay and rockfill zones. Because the embankment material properties are unknown, soil piping resulting from seepage cannot be evaluated. However, spring and seepage water was flowing clear at the time of this investigation. The riprap protection appears adequate up to the layer of clayey sand which was placed in 1977. This layer is highly erodible and is inadequately protected from erosion due to wave action. Erosion is present along the crest and right abutment, but does not presently create a safety hazard.

3.1.3 Spillway

The spillway system was designed to accommodate a smaller flood event than required by current standards. Maximum spillway capacity, assuming the reservoir pool is at the first overtopping dam crest elevation (8325.2 feet, see note on page viii) is approximately 520 cfs. The flood surcharge storage capacity between the spillway crest (elevation 8322.0 feet) and the first overtopping dam crest elevation amounts to 260 AF. In comparison, the August thunderstorm PMF for the 1.9 square-mile drainage area is estimated to have a total 6-hour runoff volume of about 880 AF. The combination of reservoir storage and spillway discharge capabilities is inadequate to prevent overtopping of the dam during the PMF runoff event.

The spillway is in generally good condition. The concrete sill which acts as the spillway crest has seriously deteriorated. Timber debris brought into the reservoir by snow avalanches poses a threat to maximum spillway discharge capacity.

3.1.4 Outlet Works

The outlet works facility appears to be in satisfactory operating condition. It was not possible to inspect the inlet or the interior of the pipe due to the pool level at the time of the survey and the small diameter of the pipe. Deterioration was noted in the following areas of the gatehouse: the exterior walls; the sealant between the walls and roof; and the hatch cover. The wooden flume located downstream of the metal pipe was also in poor condition. Discharge capacity of the outlet works is estimated to be 16 cfs at both the spillway crest (elevation 8322.0 feet, see note on page viii) and the first overtopping dam crest elevation (8325.2 feet). Since the valves are at the downstream toe of the dam, the conduit through the embankment is subjected to the full head of the reservoir when either valve is closed. A leak in this pressurized conduit could lead to failure of the dam. This is particularly important since the dam is old and the condition of the metal conduit is unknown. If the metal conduit is free within its masonry culvert, a pressure build-up adjacent to the embankment material would be less likely.

3.1.5 Operation and Maintenance

There is a general operation plan for Storm Lake which is dictated by seasonal runoff/storage and downstream water requirements. There are no formal flow/storage measurement or maintenance programs. Inspections of the dam and appurtenance structures are made at least a couple of times a year, but are only general in nature. It appears that all items requiring maintenance and repair in the past have been identified and

remedial work performed by Anaconda Copper Mining Company personnel and equipment. The hasp and lock on the hatch cover to the gatehouse was out of service, which allows unauthorized entry to the outlet control valves. Because of the remoteness of the damsite and the fact that access by four-wheel drive vehicles is available only a few months during the year, the project is considered to have an operational constraint. A warning plan to alert downstream inhabitants of dam distress has not been developed.

3.2 RECOMMENDATIONS

- (1) Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam distress. Coordinate the plan with any emergency and operation plans at Silver Lake.
- (2) Using suitable material, fill and properly compact all localized depressions along the dam crest.
- (3) Place additional riprap along the upstream side of the dam crest to prevent wave erosion of the highly erodible layer on the crest.
- (4) Perform the following repairs to the spillway: repair the surface of the concrete sill in the spillway; remove the debris from the spillway approach channel; and install a log boom.
- (5) Perform the following repairs on the outlet works: perform a detailed evaluation of the condition of the outlet pipe and gatehouse and make the necessary repairs; repair the wooden flume and/or extend the metal pipe at the downstream end of the outlet works; and provide the necessary means for energy dissipation if the outlet is modified. Consider adding an emergency closure valve at the upstream end of the outlet pipe.

The above recommendations will not make the project safe but will reduce involved risks while the following recommendations with subsequent actions are being accomplished.

- (6) Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity and modify the project as studies indicate.
- (7) Repair the erosion on the dam crest and at the right abutment contact at the downstream toe in the roadway.

- (8) Monitor seepage flows periodically for evidence of boils or piping and long-term changes in flow. Make appropriate changes if needed.
- (9) Continue to monitor the riprap protection on the spillway approach channel sideslopes.
- (10) Conduct an inspection of the dam with the presence of a qualified geotechnical engineer at least once every five years. Include an inspection of the total length of the outlet pipe.
- (11) Maintain an active maintenance plan particularly with respect to the outlet works gates and debris removal in the spillway channel.

Contact the Montana DNRC, Dam Safety Section, prior to performing engineering studies and remedial construction to insure compliance with all pertinent laws and regulations.

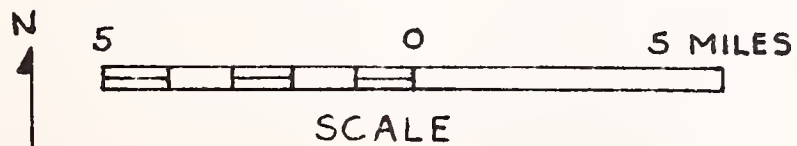
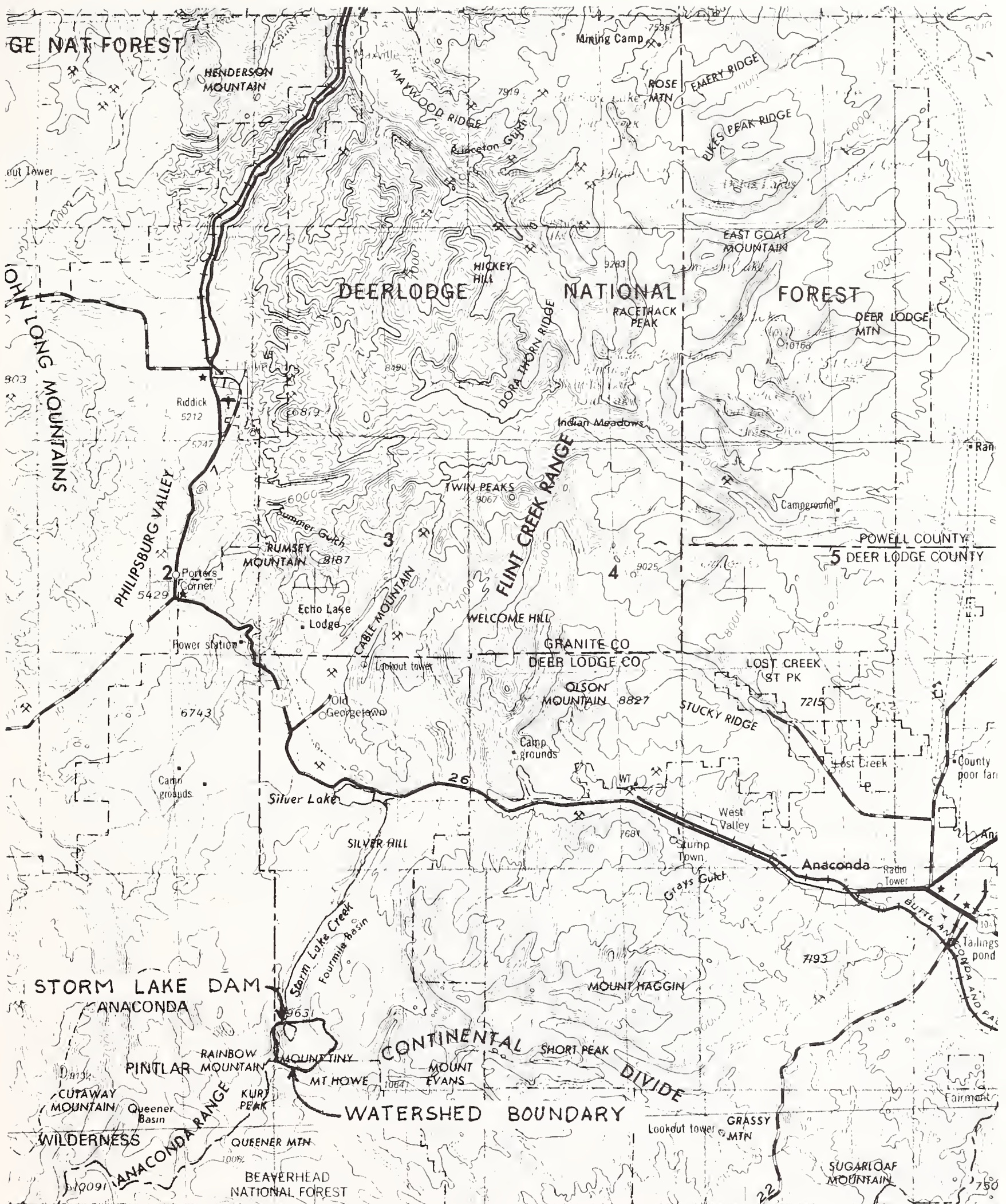
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APPENDIX A

VICINITY & WATERSHED MAP



SOURCE: BUTTE, MT. AMS MAP, USGS

APPENDIX A VICINITY & WATERSHED MAP STORM LAKE DAM

APPENDIX B
INSPECTION PHOTOS



Photo No. 1 - Dam

Photos 1 and 2 are a pan of Storm Lake Dam. The spillway is located on the left (west) side of the dam. Timber debris is present in the spillway approach channel and along the spillway banks.



Photo No. 2 - Dam

See Photo No. 1



Photo No. 3 - Watershed
The upstream watershed consists of alpine terrain.



Photo No. 4 - Spillway
The spillway approach section is lined with rock.
Timber debris is present along the channel bottom.



Photo No. 5 - Spillway

The concrete sill which performs as the spillway crest is in the foreground. At the time of the September 1980 survey it was nearly buried with timber debris. The spillway return channel begins at the break in slope where the riprap ends.



Photo No. 6 - Outlet Works

The exterior walls of the gatehouse are in poor condition. The mortar between the rocks is cracked and the sealant between the rock and the roof has separated.



Photo No. 7 - Outlet Works

The gatehouse is located in the foreground. The outlet discharges into Storm Lake Creek across the road from the gatehouse. Seepage water from the dam is flowing adjacent to the gatehouse.



Photo No. 8 - Dam Embankment

This photo is looking along the dam crest towards the right (east) abutment. The clay/sand layer was placed on the crest in 1977. The measured crest width varies from 13 to 17 feet.



Photo No. 9 - Dam Embankment
Some debris is evident on the upstream slope of the dam. The clay/sand layer on the crest was placed in 1977.



Photo No. 10 - Dam Embankment
The riprap consists of loose quartz and quartz monzonite, and is in excellent condition. Debris is evident on the upstream face.



Photo No. 11 - Dam Embankment

The embankment is earth and rock fill and appears stable. The downstream face of the embankment has a slope of about 33 degrees or 1V on 1.5H.



Photo No. 12 - Dam Embankment

High seepage flows are evident at the downstream toe of the dam. Seepage water is shown exiting from the lowest point on the downstream slope.



Photo No. 13 - Dam Embankment
Seepage water is ponded at the downstream toe of the dam.



Photo No. 14 - Dam Embankment
High seepage flows are evident through the abutments and under the dam. Free flowing springs are shown here approximately 75 feet below the left abutment. The ground is saturated throughout the valley floor immediately below the dam.



Photo No. 15 - Reservoir

Snowslides and small landslides have occurred along the reservoir shoreline. The reservoir banks are near vertical to heights of about 10 feet in places.



Photo No. 16 - Dam Embankment

Water is ponding on the crest in several locations. Runoff or spillage of ponded water is causing some erosion in the sand as can be seen in the far left of this photo.

APPENDIX C

PROJECT DRAWINGS

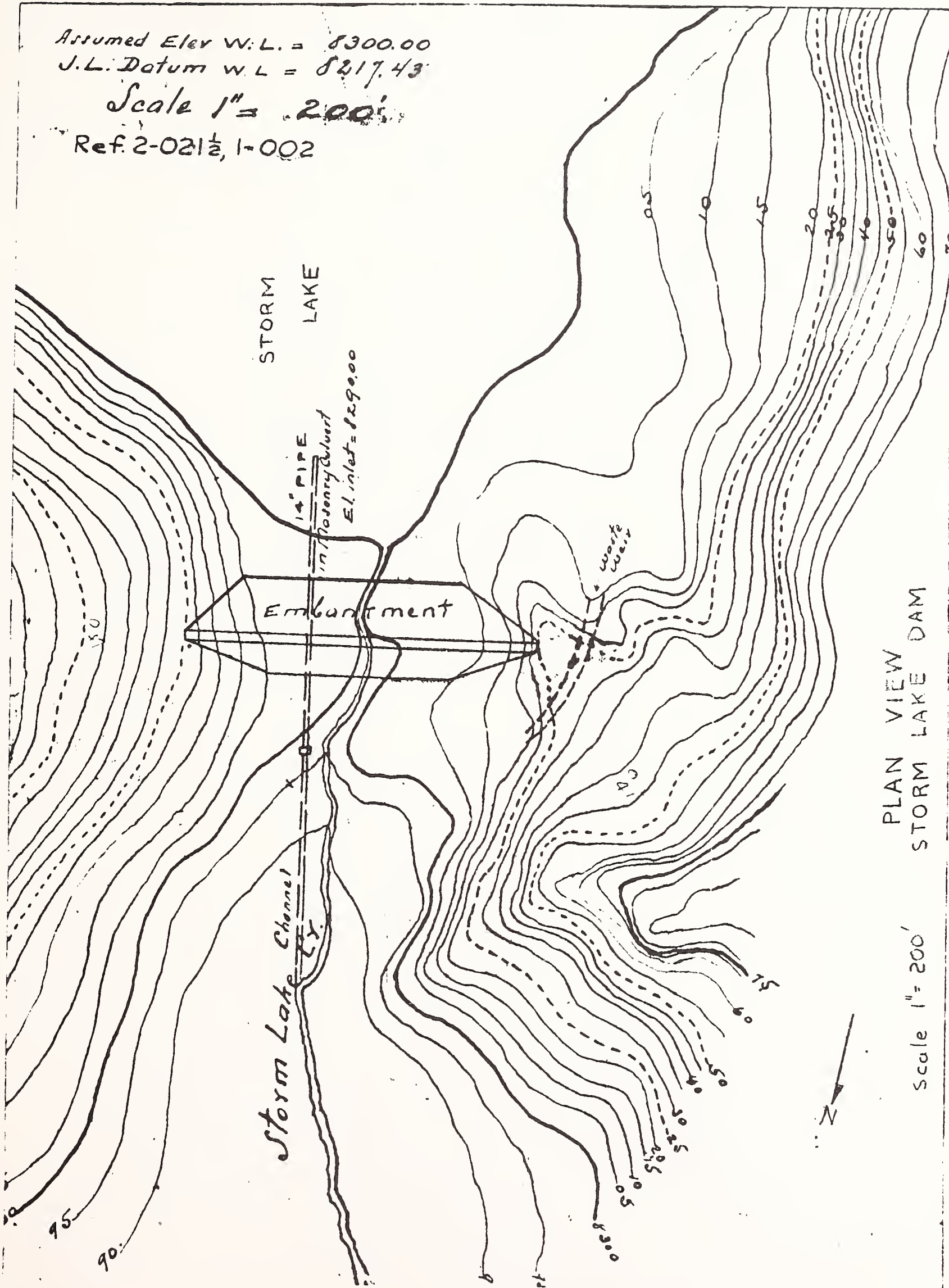
EXHIBIT C1	CONSTRUCTION PLANS
EXHIBIT C2	DAM CREST PROFILE
EXHIBIT C3	MEASURED EMBANKMENT SLOPES
EXHIBIT C4	SPILLWAY PLAN & PROFILE

Assumed Elev W.L. = 8300.00

J.L. Datum W.L. = 8217.43

Scale 1" = 200'

Ref. 2-021 $\frac{1}{2}$, 1-002



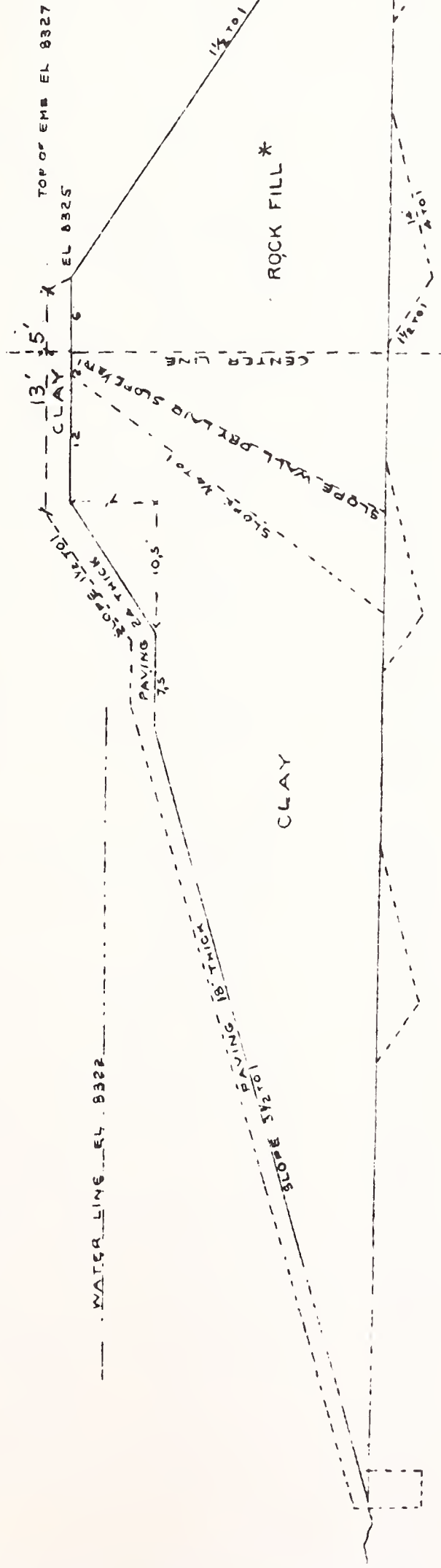
PLAN VIEW DAM
STORM LAKE

Scale 1" = 200'

A.C.M. CO.

DAM AT STORM LAKE

SCALE 1"=100 FT
14.3'

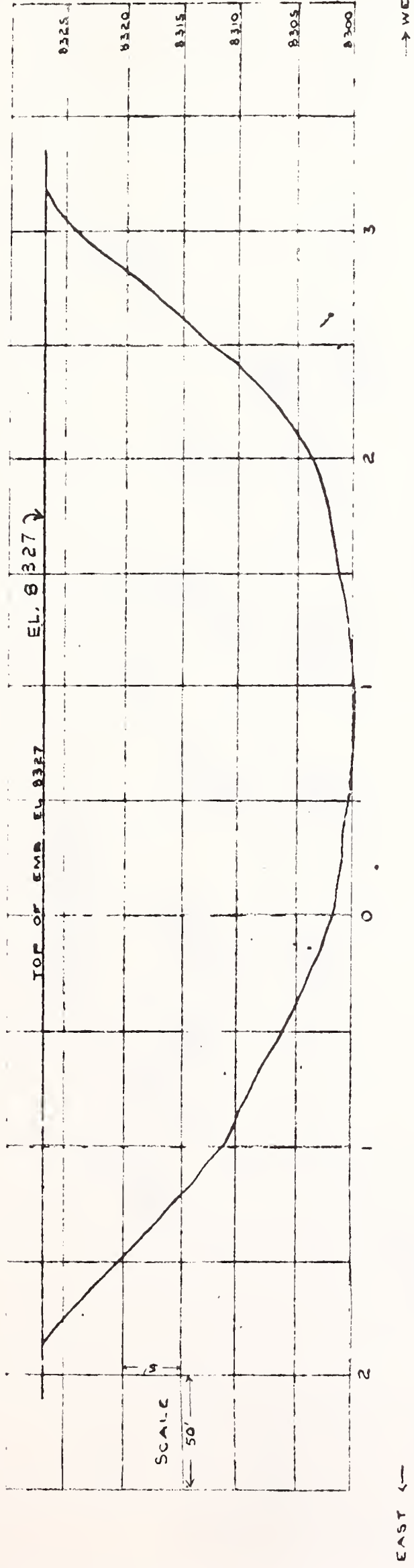


CROSS-SECTION AT STA 1. WEST. **

APPROX. QUANTITIES.

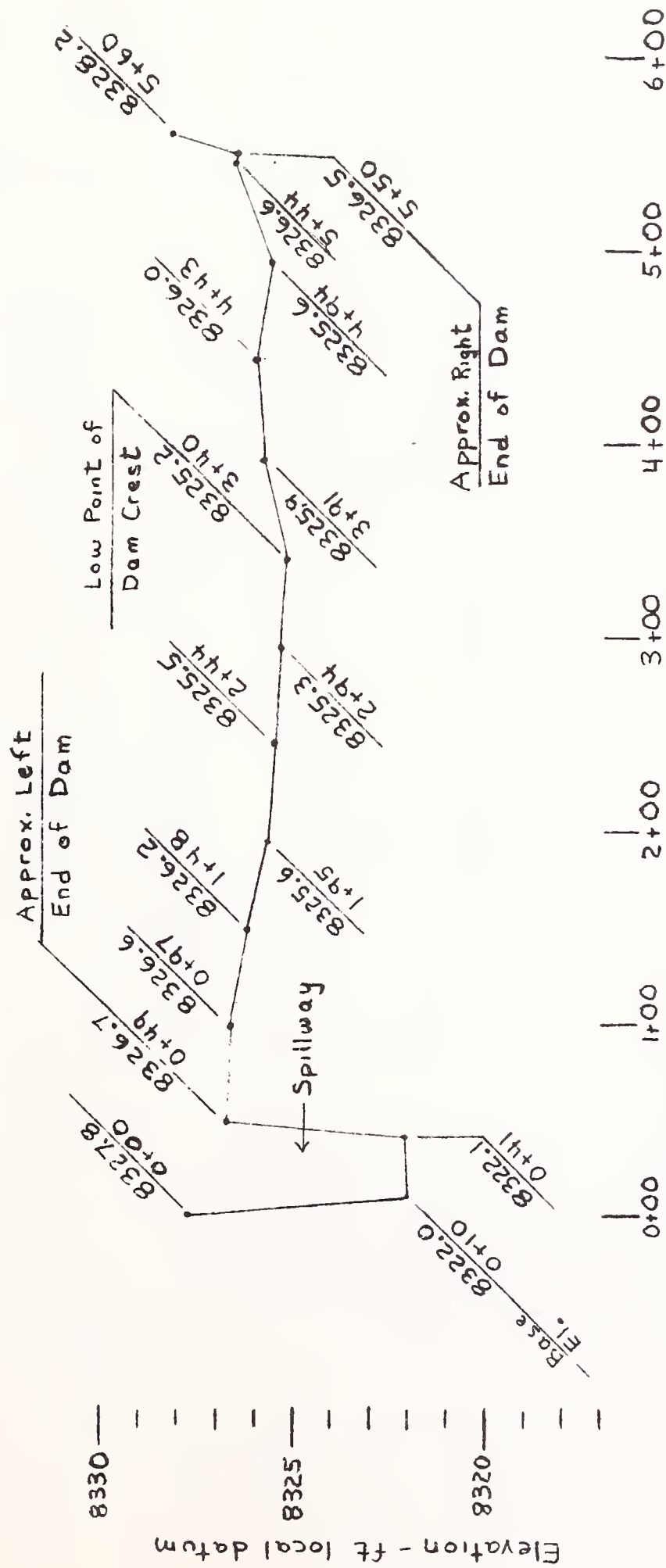
CLAY EMB.	15000 YDS
ROCK FILL	8000
DRY SLOPE WALL	800
RIP-RAP	1200
LOOSE ROCK EXC.	3000

* Extent of rock fill in embankment unknown
** See Sheet 3, Exhibit C1



STORM LAKE DAM PROFILE

3-1-017



Station - ft
Scale: 1"=100'H, 1"=5'V

NOTES:

1. Profile derived from HKM field survey 9/30/80
2. Elevations based on setting left side spillway crest = El. 8322.0 ft local datum

EXHIBIT C2 DAM CREST PROFILE STORM LAKE DAM

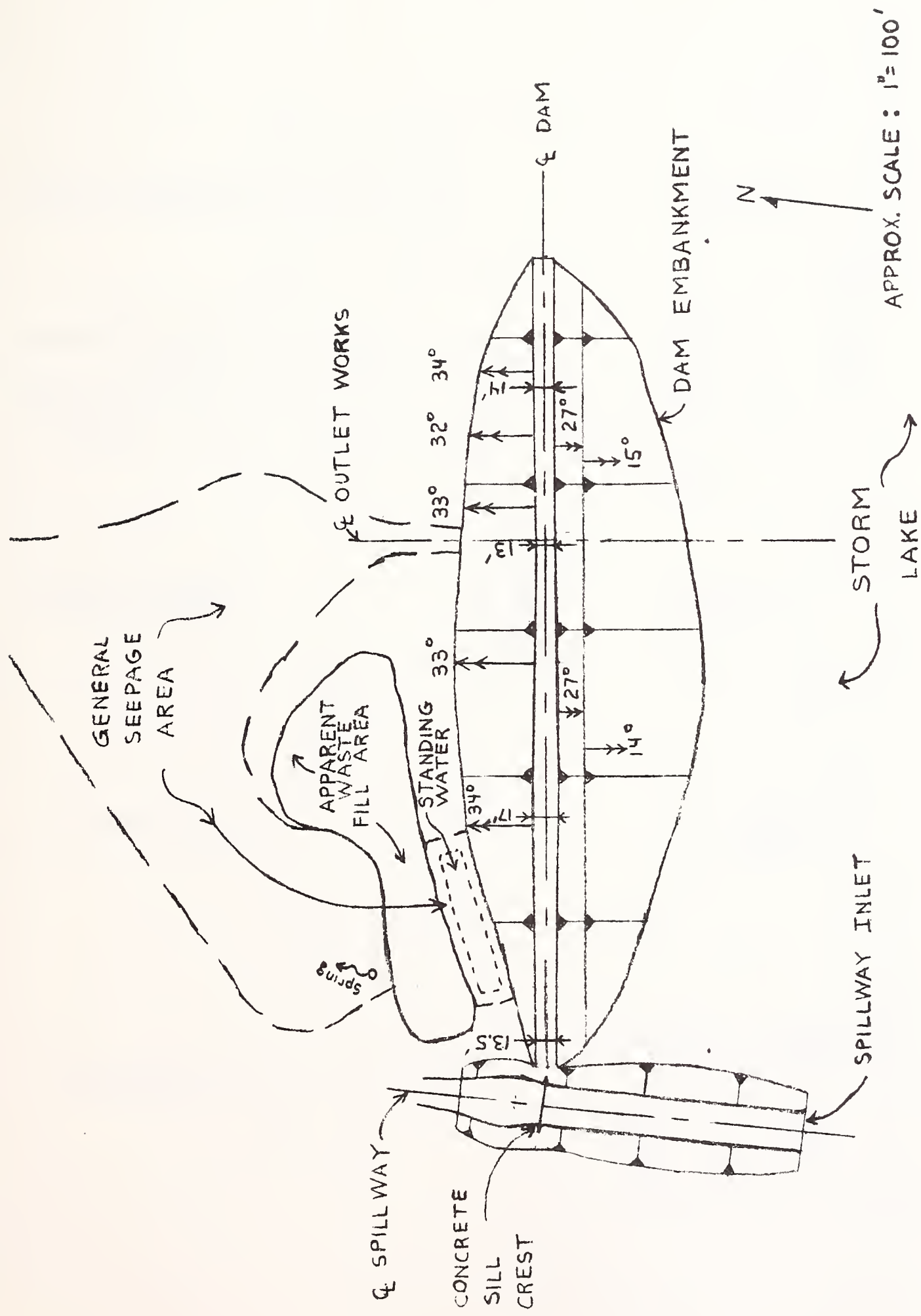
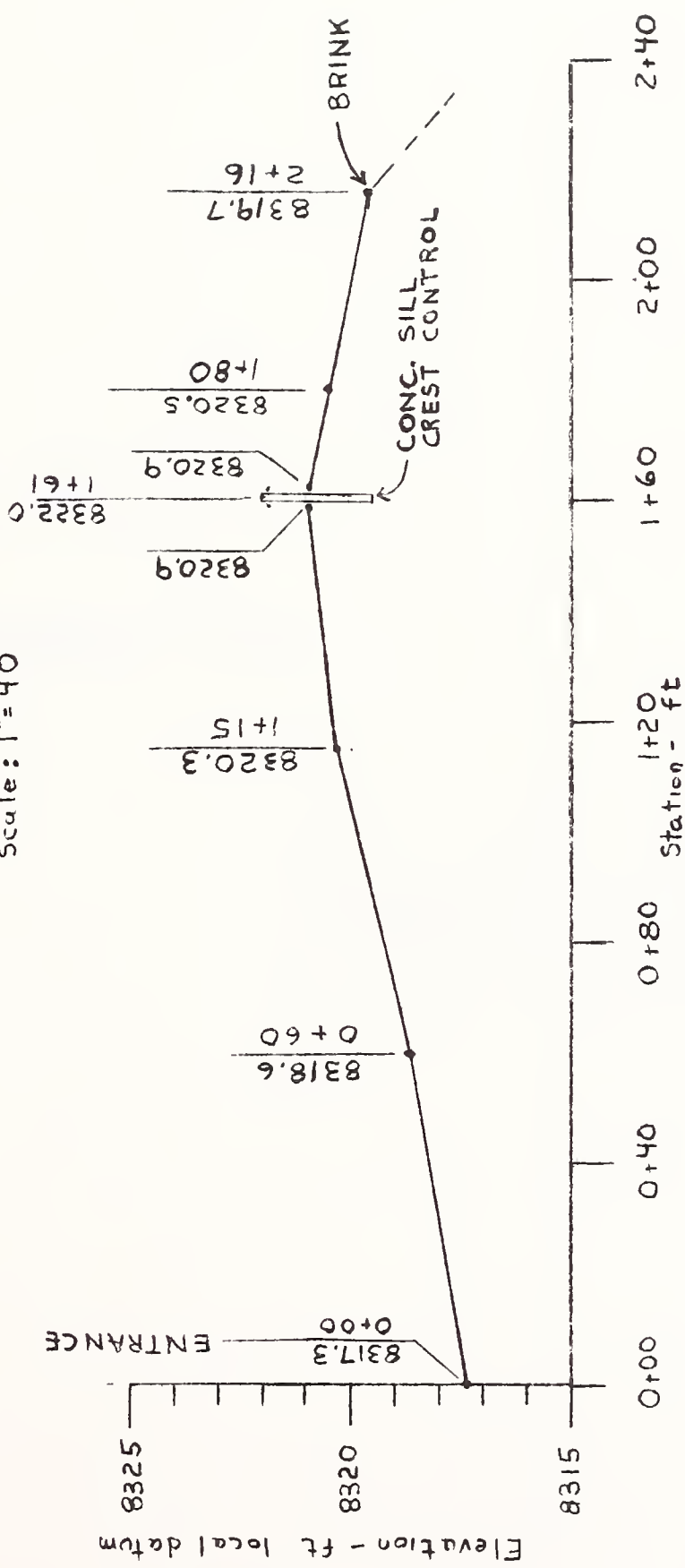
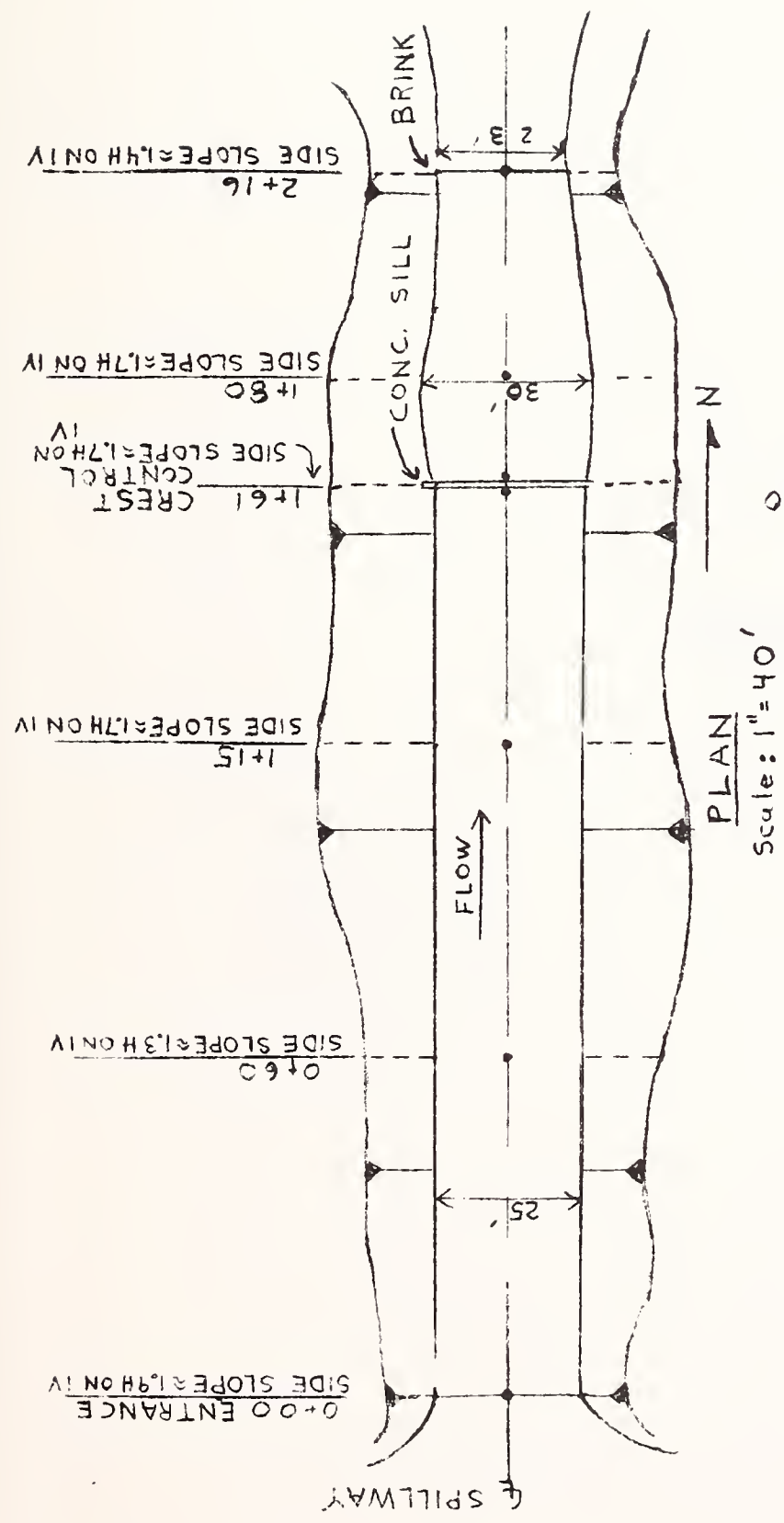


EXHIBIT C3
MEASURED EMBANKMENT SLOPES
STORM LAKE DAM

EXHIBIT C4 SPILLWAY PLAN & PROFILE STORM LAKE DAM



APPENDIX D

ENGINEERING DATA

EXHIBIT D1

ELEVATION-AREA-STORAGE CURVES

EXHIBIT D2

DISCHARGE RATING TABLE

EXHIBIT D3

DISCHARGE RATING CURVES

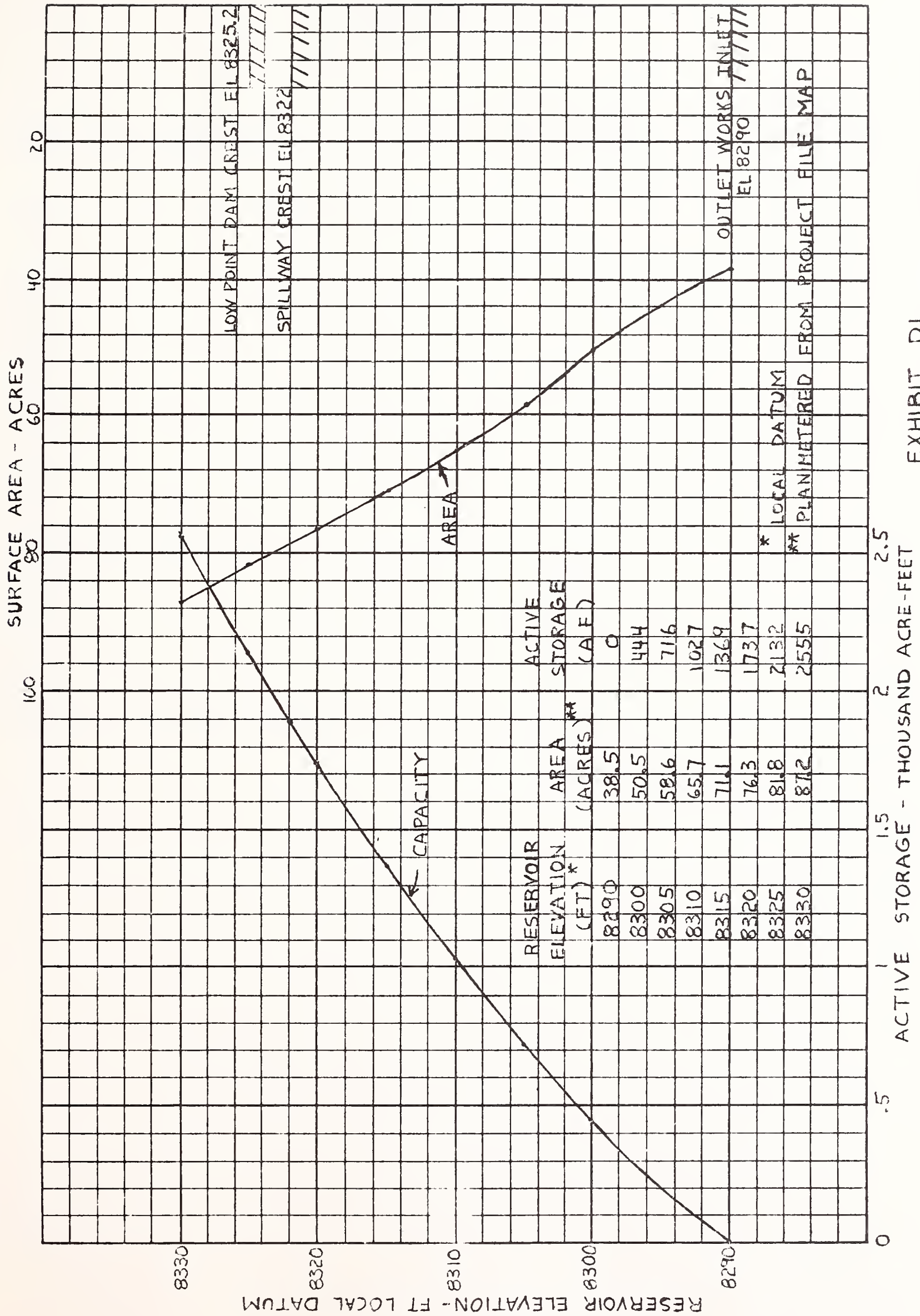
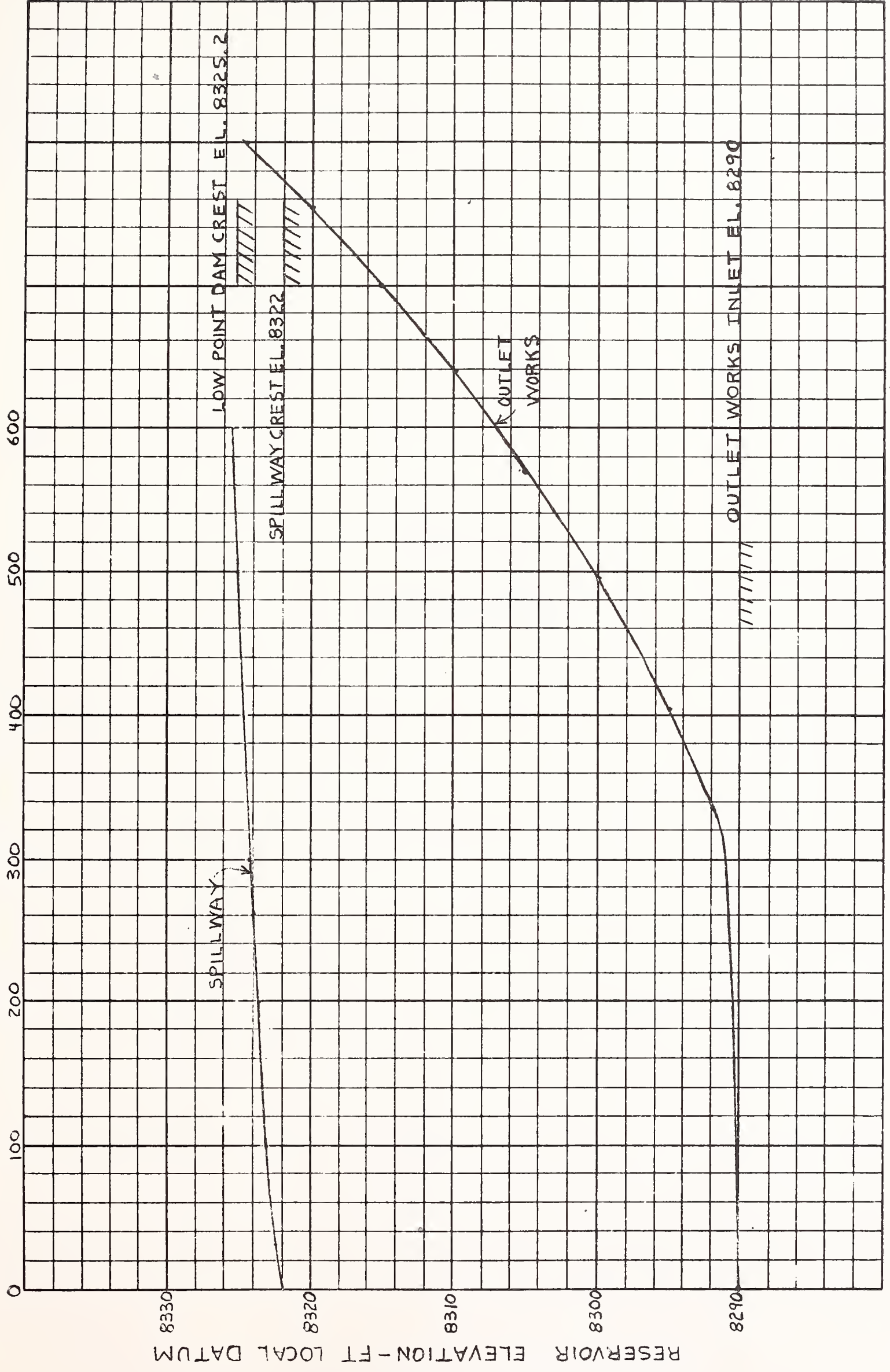


EXHIBIT D1
ELEVATION-AREA-STORAGE CURVES
STORM LAKE DAM

EXHIBIT D2
DISCHARGE RATING TABLE
STORM LAKE DAM

<u>Reservoir Elevation</u> <u>(ft, local datum)</u>	<u>Outlet Works</u> <u>Discharge</u> <u>(nearest cfs)</u>	<u>Spillway</u> <u>Discharge</u> <u>(cfs)</u>
8290 (outlet works inlet el.)	0	---
8295	8	---
8300	10	---
8305	11	---
8310	13	---
8315	14	---
8320	15	---
8322 (spillway crest el.)	16	0
8323	16	100
8324	16	260
8325	16	470
8325.2 (low point dam crest el.)	16	520

SPILLWAY DISCHARGE - CFS



0 100 200 300 400 500 600

0 2 4 6 8 10 12 14 16

EXHIBIT D3
DISCHARGE RATING CURVES
STORM LAKE DAM

APPENDIX E
CORRESPONDENCE

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION



TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

May 19, 1981

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Ralph:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Storm Lake Dam (MT-1357). We concur with the findings and recommendations and feel that it satisfies the criteria of the Phase I evaluation.

Minor editorial comments have been discussed with your staff, and we understand these will be included in the final report.

Thank you for the opportunity to review and comment on the final draft report for this project.

Sincerely,

A handwritten signature in cursive script that reads "Richard L. Bondy".

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB:LT:lz



ANACONDA Copper Company

555 Seventeenth Street
Denver, Colorado 80202
Telephone 303 575 4000



May 1, 1981

Sidney Knutson, P.E.
Assistant Chief, Engineering Division
Department of the Army
Seattle District, Corps of Engineers
P. O. Box c-3755
Seattle, Washington 98124
Dear Mr. Knutson:

I have been asked by Dr. Krablin to reply on his behalf to the Phase I Inspection Report on the Storm Lake project dated April 1981, and we are contracting with a reputable geotechnical firm to proceed with the hydrologic and hydraulic routing studies and inspections as recommended.

Once we have received the report on these studies, a copy will be forwarded to the Governor of the State of Montana.

Sincerely,

John C. Spindler

JCS/ld

enclosures

pc/enc: Mr. Leo Berry, Jr., Director
Department of Natural Resources and Conservation
32 S. Ewing
Helena, Montana 59601

